Mars Gravity Field from Dual Satellite Observations

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Accurate determination of the Martian gravitational field is very essential, especially for missions und er consideration for human exploration[1] of Mars. There are stringent navigational requirements[2] during critical phases such as aero-assisted maneuvers including landing, which require a detailed and accurate description of tile gravitational field. Landing within 5 to 10 meters of the target site and locating elements on the surface of the planet from orbiting satellites within 3 meters, are some of the objectives presently considered for these missions. This paper examines the feasibility of improving the accuracy with which the gravitational field can be determined from dual sate'llite observations.

Spherical harmonic representations of the Martian gravity field of various degrees (and orders) are available from NASA's Viking Mission. The Balmino gravity model for Mars of degree 18, and higher order representations such as the 30th and 50th degree Mars gravity field from NASA Goddard Research Center are results obtained from Viking navigation data. 'J'lime results will be further refined from data obtained from the Mars Observer (MO) mission currently in progress, particularly during the gravity calibration phase,

There will be a unique opportunity in the next two or three years, to obtain a highly accurate Mars gravit y field from the Mars Observer (U.S.) mission and the Mars 94 (Russian) mission. The MO spacecraft is in a nearly circular orbit (eccentricity, e = 0,00725) with a semi-major axis of ***3775*** km and at an inclination of 92.87°. The Mars 94 spacecraft is in a highly eccentric orbit (eccentricity, e = 0.708) with a semi-major axis of 12650 km and at an inclination of 90 degrees. It is prop osed that these two spacecraft be observed with 2-way and 3-way Doppler data (including provisions for differenced data whenever feasible) from the 3 NASA Deep Space Network tracking stations at Goldstone, Canberra and Madrid and from the Russian tracking stations at Yevpatoriya and Ussuriisk. With different combinations of these navigation data to the two satellites, tile Mars gravity field will be further refined.

Our preliminary statistical studies with analysis in the frequency clomai]l[d]'6 indicate definite improvements to the gravity field from dual satellite observations. When the two satellites are near their respective periapses, information (transfer function) is obtain ed as for the case of the "low-low satelite" con figuration[4,5] with a small angular separation in their ground-traces. When the Mars 94 satellite: is near its apoapsis, the "high-low" configuration[4,5] provides the corresponding information]]. Apart from the assumption of a "flat Mars", numerous other assumptions also on tile visibility of the two spacecraft, scheduling of observations and data noise for the relative velocity measurements have been made, for analysis in tile frequency domain.

Detailed work on the determination of Mars gravity field from various combinations of radiometric data to the MO and the Mars 94 spacecrafts is Presently under way at the Jet Propulsion Laborator y. The covariance analysis is being carried out with a multi-satellite navigation analysis software (LEXUS), and the detailed results of this study will be presented in the paper. The geometry for radiometric observations on the two spacecrafts, assumptions on the orbital parameters and anticipated "actual" tracking of Mars 94 and a list of various combinations (of data) for covariance analysis are indicated in the viewgraphs attached. Preliminary estimates based on very approximate analysis in the frequency domain indicate that improvements by factors varying from 2 to 10 (depending on the wave number) can be obtained in the degree variances in the gravity field. The details for computer simulations for the covariance analysis and the final results will be presented in the paper.

Acknowledgements

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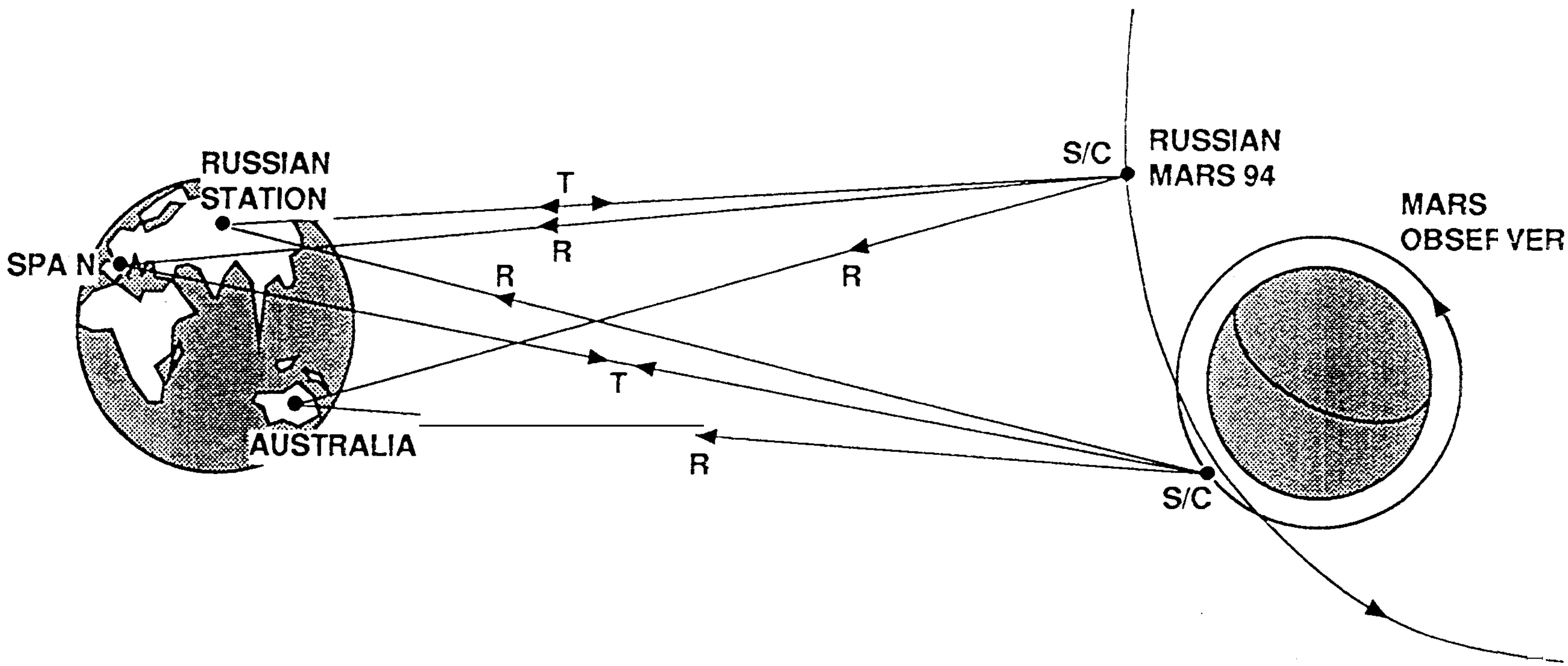
MARS OBSERVER AND MARS 94 GEOMETRY



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ASSUMPTIONS ON MARS 94

- SEMI-MAJOR AXIS = 12650 KM

  ECCENTRICITY = 0.705

  INCLINATION = 90°

  ALTITUDE AT PERIAPSIS = 300 KM

  PERIOD = 12 HRS

- PERIAPSIS TRACKED ON EVERY ORBIT
- TRACKING DURATION ONE HOUR TWICE PER DAY
- RECORD BOTH 2-WAY FROM MARS-94 AND 3-WAY FROM M.O.
- SAMPLE RATE OF ONE EVERY 10 sec

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STATISTICAL STUDY ON A MARS GRAVITY FIELD DETERMINATION

- 86 ORBITS OF MARS ORBITER (M.O.) (GLOBAL COVERAGE) WITH 2-WAY DOPPLER ONLY
- ADD 3-WAY DOPPLER (M.O.) (U.S. ONLY)
- ADD 3-WAY DOPPLER M.O. (U.S. AND RUSSIAN)
- 80 ORBITS OF MARS 94 (GLOBAL COVERAGE) WITH 2-WAY DOPPLER ONLY
- ADD 3-WAY DOPPLER MARS 94 (RUSSIAN ONLY)
- ADD 3-WAY DOPPLER MARS 94 (U.S. AND RUSSIAN)
- COMBINE M.O. AND MARS 94 (2-WAY DOPPLER ONLY)
- COMBINE M.O. AND MARS 94 (ALL DOPPLER)
- COMPARE COEFFICIENT VARIANCES
- COMPARE GLOBAL GEOID UNCERTAINTY MAPS

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